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New Perspective to Unlock Opportunities in Mature Field: Sanga-Sanga Block, Indonesia

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Abstract

Sanga-Sanga Block is located onshore of the Mahakam delta, in East Kalimantan Indonesia and operated under Pertamina Hulu Sanga-Sanga. Nilam field, one of assets in Sanga-Sanga Block was discovered in 1974 with 75 km length. Nilam field was interpreted as the extension of Badak Handil Anticline Structure. The first well, NLM 1 was spudded on 8 July 1974 and put on production 9 years later due to waiting on surface facility. Early production was 22 MMscfd and flow directly to Bontang. At present, Nilam has reached a mature stage of its life where 364 wells drilled. The productions are continuing declining and currently 98 wells online and deliver approximately 23 MMscfd and 1800 BOPD.

There are 3 components to generate the production; they are base, rigless and new well program. New well program is main contributor to Nilam production. However, since oil price start to drop in 2014, drilling activity becomes decreased and consequently, rigless activity become the main backbone to arrest production decline. Aggressive rigless program is required to maintain Nilam production. Since 2010, total of perforated zones are 1323 and by the time, thus remaining zone candidates for rigless are decreasing. To face this challenge, integrated subsurface review has been conducted to assess several strategies to create new opportunity in delivering Nilam production. The strategies are; unlocking the hidden potential from by passed and unprognosed zones in existing well and campaign of complex rigless program to access the potential zones.

In early 2018, these strategies has already applied and already contributed 4.42 Bcf and 164 thousands of barrel oil to Nilam Field. The success ratio is 73%. It helped to sustain Nilam production and maintain the decline rate. In summary, these strategies have successfully unlocking hydrocarbon potential and maximizing recoverable reserve in existing wells which resulted in extend the field life. This paper will describe the success story to unlock gas and oil reserve in complex environment especially at Nilam Field.

Introduction

Nilam field was discovered back to 1974 with his first well NLM-01 was spudded on July 8th, 1974. Nilam field is located in Kutai Basin, East Kalimantan, Indonesia. It has characteristic with fluvial deltaic reservoirs, of age Early-Middle Miocene (Figure-1). At the moment, Nilam has been categorically defined as mature field of its life where 364 wells drilled and already produced with cumulative production of 4.4 TCF of gas, 46 MMbbls of oil and 59 MMbbls oil condensate. With almost 45 years of exploitation, these still have significant reserves of gas in regards of low quality reservoir rocks in structural, stratigraphic or combination traps, suspiciously not entirely examined. Meanwhile, production flowrate are on declining phase with current production approximately 14 MMscfd and 609 BOPD with only 98 active wells delivered.

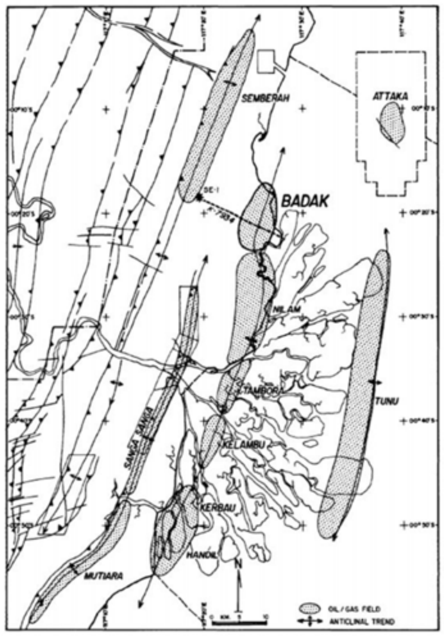

Figure 1—Structural Map Oil and Gas

Nilam field is known by wide type of reservoir structure with thousands of reservoir unit varying from small lens reservoir up to multi-story stacking channels sandstones due to combination of a complex fluvial-deltaic depositional environment of channel/mouth-bar sands. Based on hydrocarbon characteristic, gas usually laid on below 10,000 ft while oil often to found shallower than 10,000 ft (Figure- 2).

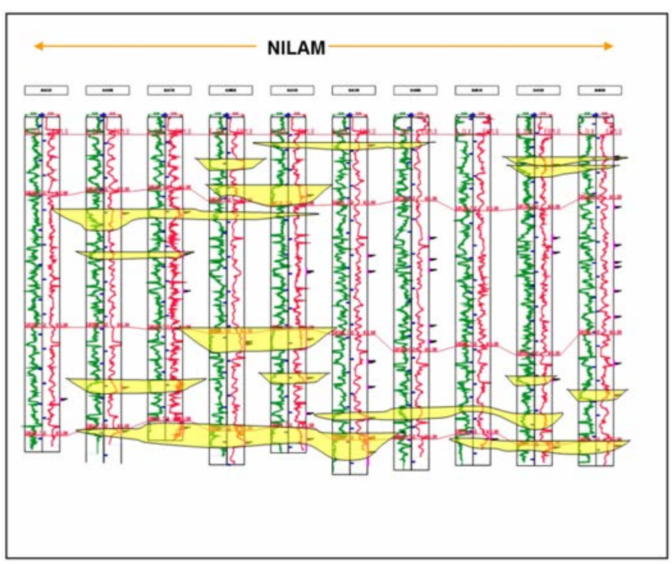

Figure 2—Reservoir type in Nilam

The Nilam field can generally be considered as being divided into three distinct 'layers/types' of sands:

1. The shallow reservoirs (C-D sands) consist of mostly of thick lenses of high porosity and permeability sand, strong water drive mechanism,
2. The middle reservoirs (E-F sands) consist of sand with various thickness, porosity, and permeability sand. Depletion drive mechanism is the usually found, but in some cases, water drive also can be found.
3. The deepest reservoirs (G sand), consist of mostly of thick lenses but was low permeability and porosity, was deposited mainly in the delta plain as fluvial channel with mostly depletion drive mechanism.

After more than 45 years of production Nilam field where most of the penetrated reservoirs/tanks have been depleted from their initial pore-pressure conditions, drilling has been main development program. Figure 3 shows Nilam production since 2010 and from that graphics could be seen that the highest number wells drilled (28 wells) in 2010 delivered the highest contribution to Nilam production. Since oil price tend to drop lately in 2014 and drilling would be luxurious things to be managed drilling activity has been decreased started in 2015 with 2016 recorded that no wells being drilled in Nilam. Thus rigless acti vity becomes the main activity to maintain production sustainability.

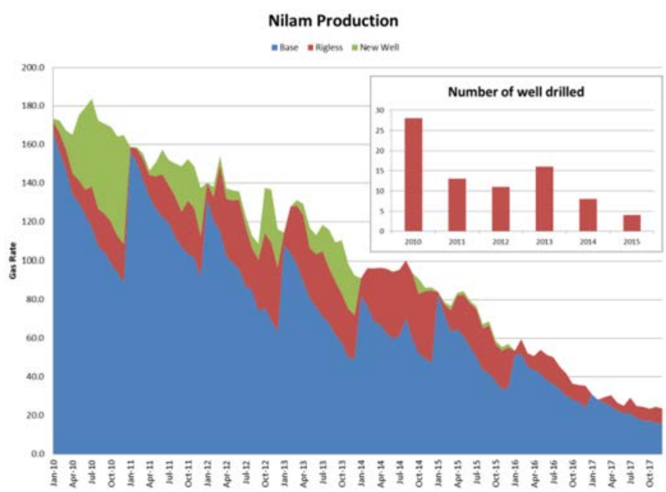

Figure 3—Nilam Productions since 2010

Lately, well review activity has been instensively conducted since the main focused has been sliding into rigless operation. The purpose is to identified and defined new additional reserves opportunity (production related) parameters, such as the permeability/porosity, pore-pressure, sand–thickness, water-saturation, offset well productivity in order to determine the most appropriate development of the reserves on each level/tank. In addition to that, since 2010 the numbers of total perforated zones reaching 1323 times. Based on those circumstances & desired parameters, this paper will describe success strategies which have been applied in Nilam these recent years.

METHODS

Unlocking the Hidden Potential in Existing Wells

With the absence of drilling program, rigless program has to be more aggressive to maintain the production. Before promoting rigless program, well review is performed to collect the zones candidates. Figure 4 shows common well review method which is started by well evaluation that has low production. Literally in one well, there are more than 100 zones penetrated. Zone by zone checking is required to find the candidate of potential zones that will be assessed. The zones assessment generally consists of two steps, static condition and dynamic condition review. Static condition is initial condition of the zone at the time the well was drilled which is represented by the open hole log and mud log data. There are several common approaches of static condition review as our guidance for to identify potential zones, deep resistivity is higher than 20 ohm meter, total gas reading by mud log is more than 5x of background gas, gas effect by crossover of neutron and density, hydrocarbon by liquid fluid analysis and net pay more than 2 ft. Dynamic condition review is current condition review of the zone by evaluating surrounding wells condition that penetrated the same reservoir. Production history at surrounding wells has to be evaluated in detail to manage risk of the water contact movement and remaining hydrocarbon in place. By applying this method, the zones that will be promoted to rigless program should be maintained in good quality.

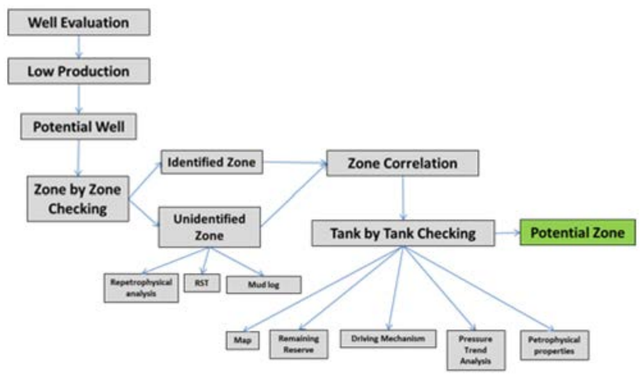

Figure 4—Well Review Method

The ideal types of potential zones are more difficult to found in limited well stock using common approach review as explained above, while the need for perforation zone candidates increased to maintain the production. To revitalize the perforation candidates, Nilam team began to shift the paradigm on how to define the potential zones. The boundary is extended into marginal zones which were overlooked with previous economic scheme. By breaking the prior boundaries with some additional supporting data, the marginal zones could become interesting to be perforated. The hidden potential zones are further classified into two categories explained below:

Bypassed zone. Bypassed zone is the marginal zone which is by passed in early exploration. It is prognosis and well defined by petro-physicist as permeable sand on open hole log but being skipped because of limited data and/or below existing petro-physic cut off value (wet zone). A sign is needed to approach the potential by pass zone for deeper well review. Gas reading from mud log data is suited for this purpose since it indicates the hydrocarbon inside the drilled rock. Subsequently, deeper well review is conducted on the potential by passed zone by revisiting the open hole log to adjust petrophysical cut off value, conducting deeper evaluation on mud log data and re-correlating to determine the connection to other wells. By doing so, it is expected the marginal bypassed zone could be shifted into prospect pay. There are several success stories from bypassed zones; E-74 Well 1, C-62A Well 2, E-59, D-57, and D-60 Well 3.

1. E-74 Well 1

   E-74 is interpreted as wet zone because resistivity value is low and small cross-over of Neutron-Density but it has high gas reading as illustrated in Figure 5. This zone is able to access at Well 18, Well 19, and well 20. Then dynamic review was conducted to update current water contact by comparing open hole log on the newer well and afterwards. At result, there was no water production in surrounding wells. This zone was perforated at well 1 and successfully flow with initial rate 4.5 MMscfd.
2. C-62A Well 2

C-62A is interpreted as wet zone because LFA data stated as water (Figure 6). Contradictory, gas reading data, resistivity value and cross-over N-D log at top part shows it is hydrocarbon. In consequence, well to well correlation is required so that this zone is most updip position with no production from surrounding wells. As a result, this zone was perforated and flow 5.1 MMscfd.

3. D-57 Well 3

D-57 is interpreted as wet based on petrophysical cut off value. Meanwhile, the resistivity value is higher than 20 ohm.m, and gas reading is higher than gas reading background on the shale (Figure 7). Based on correlation, this zone is most updip position. Downdip well has been perforated but not flow due to well integrity issue. This zone was perforated and delivered initial production 0.6 MMscfd.

4. D-60 Well 3

D-60 is interpreted as wet zone because it has low resistivity and small crossover of neutron- density log compared to F-54A zone (Figure 8). Meanwhile it has high gas reading. Based on correlation, this zone is connected to well 13 and well 14. In addition, from dynamic review, water contact is already moved up to Well J. This zone was perforated and finally flowed with initial rate 3.8 MMscfd.

5. E-59 Well 3

E-59 is initially interpreted as wet zone since low resistivity value and thin pay (below 2 ft). Shallow resistivity is lower than deep resistivity which indicates water bearing response (figure 9). By geological correlation, this zone is identified the most downdip position and connected to well 10, well 11, well 12, and well 13. These surrounding wells did not have good production. One strong justification is by gas reading value from mud log data. To strengthen the justification, it was decided to run cased hole RST Sigma-CO log to identify hydrocarbon and surprisingly the interpretation shows oil saturation is approximately 50 percent and sigma value is approximately 8 cu. Therefore, this zone was perforated and successfully delivered initial rate 2.1 MMscfd and 131 BOPD.

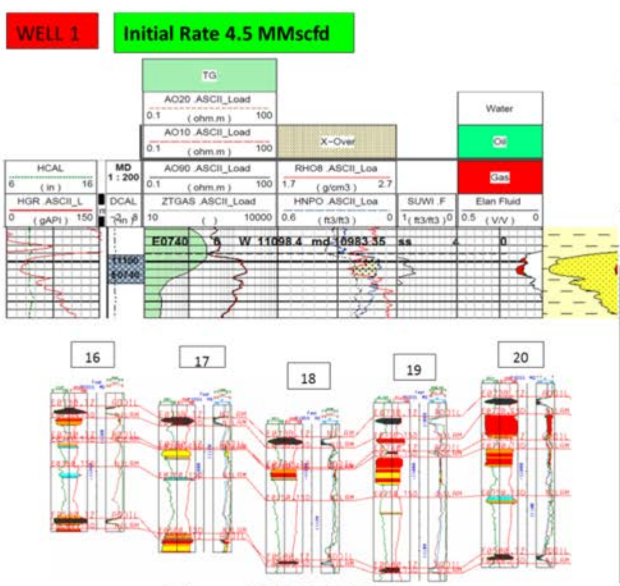

Figure 5 E-74 Well 1

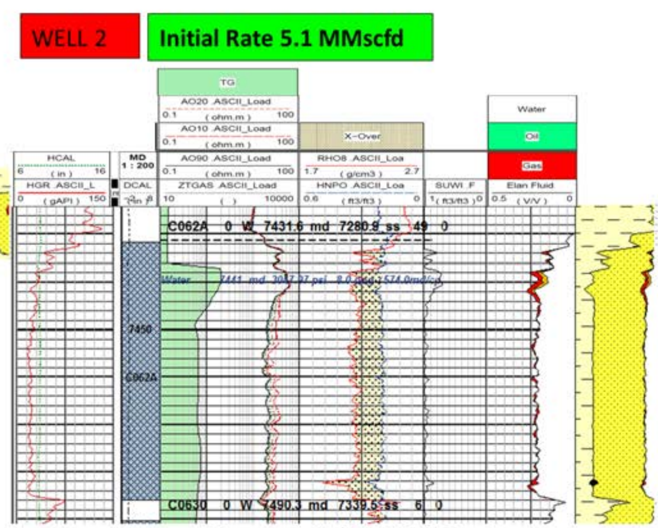

Figure 6 C-62A Well 2

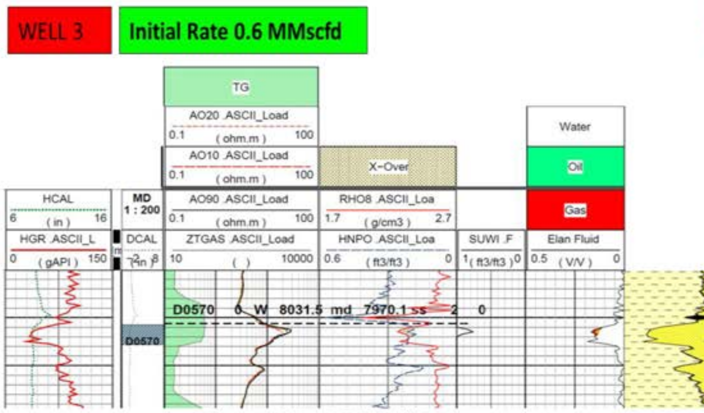

Figure 7 D-57 Well 3

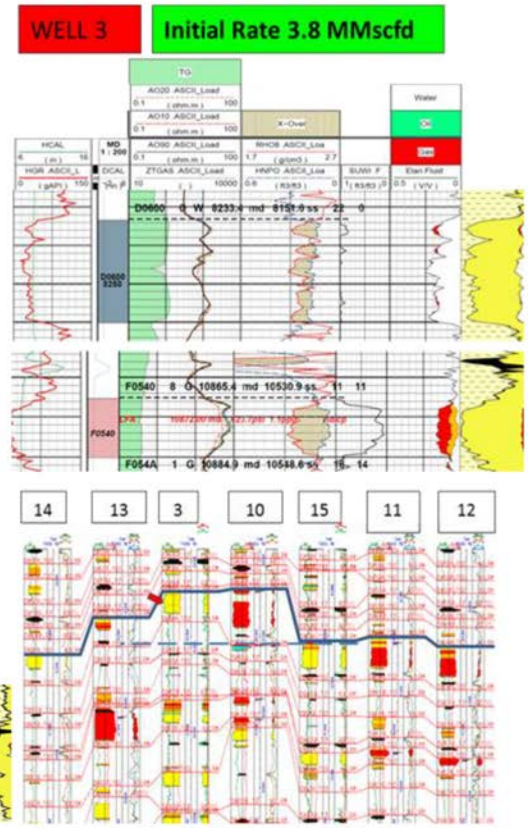

Figure 8 D-60 Well 3

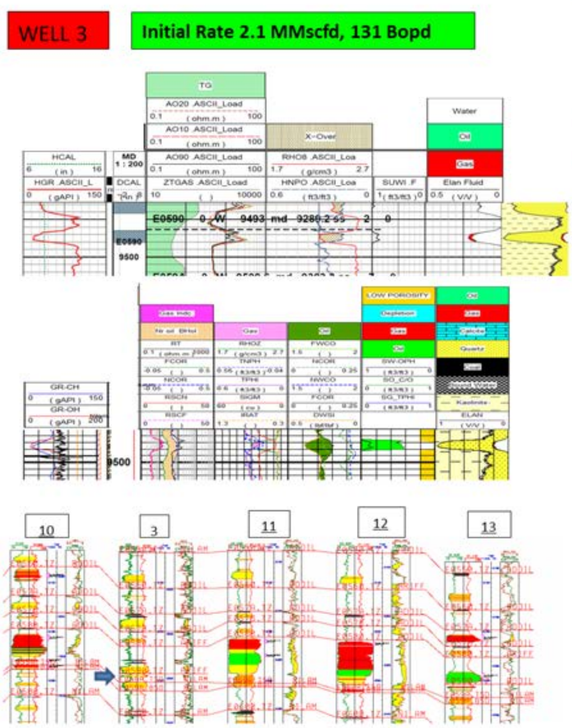

Figure 9 E-59 Well 3

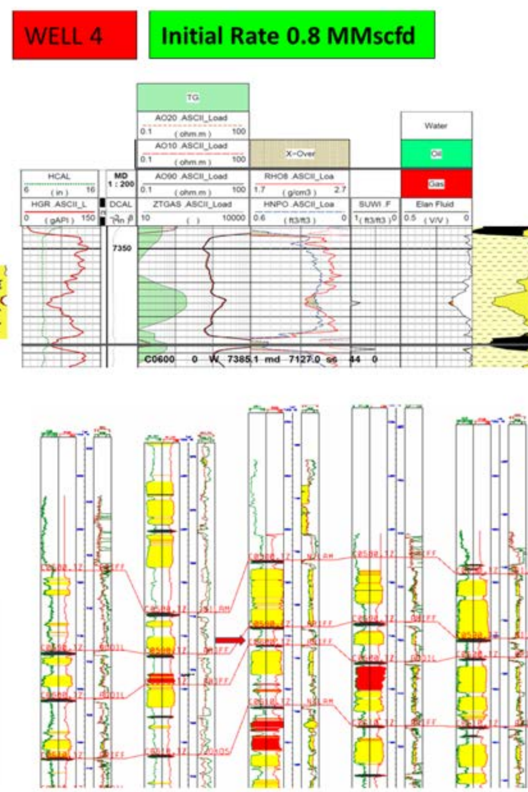

Figure 10 C-59 Well 4

Unprognosed zone. Unprognosed zone is identified as zone that is not interpreted as pay or wet zone. This zone is unpredictable as not pass the petrophysical cut off value. In some case this zone is not recorded using open hole logging process since it is located above intermediate casing. It needs more supporting data and review to find this zone such as mud log data, and re-correlation to surrounding wells. Below are several success story cases from unprognosed zones in Nilam.

1. C-59 Well 4

   C-59 is not identified as zone because resistivity, gamma ray and crossover Neutron-Density is lower than cut off pay from petrophysical (Figure 10). Meanwhile gas reading shows total gas reading from mud log is 10 times bigger than background gas. Using geological correlation, this zone is obviously connected to other wells which have been proven. Based on that, thi s zone turned into potential and successfully delivered initial gas rate 0.8 MMscfd.
2. C-65 Well 5

   C-65 is not identified as zone because it was not recorded in open hole log data. C-65 is located above intermediate casing. There is no LFA data to support the interpretation. One sign was shown by gas reading value from mud log data (Figure 11). The total gas reading is 15 times bigger than background gas. Based on correlation it is categorized as single penetrated reservoir. Hence, it was perforated and successfully deliver initial rate 6.8 MMscfd.
3. D-64 Well 6

   D-64 is not identified as zone because resistivity value is below petrophysisical cut off value. There is no LFA data but the gas reading shows it is potential. It has 116 unit of gas reading compare d to background gas 15 units. From well to well correlation, it found that this zone already developed at surrounding wells (Figure 12). Then it was perforated and deliver initial rate 2.2 MMscfd.

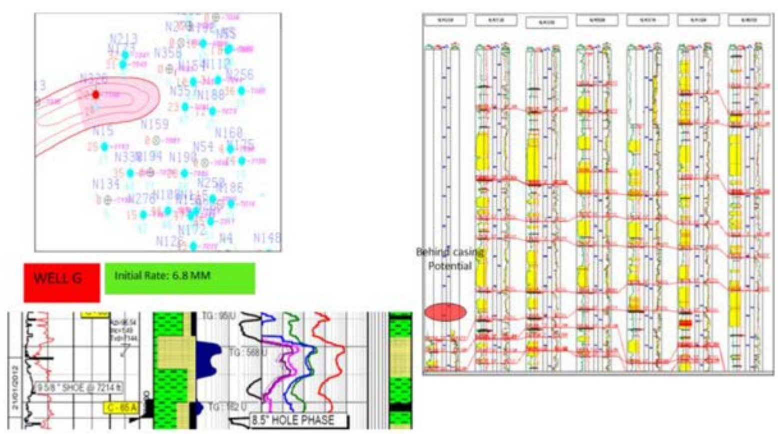

Figure 11—C-65 Well 5

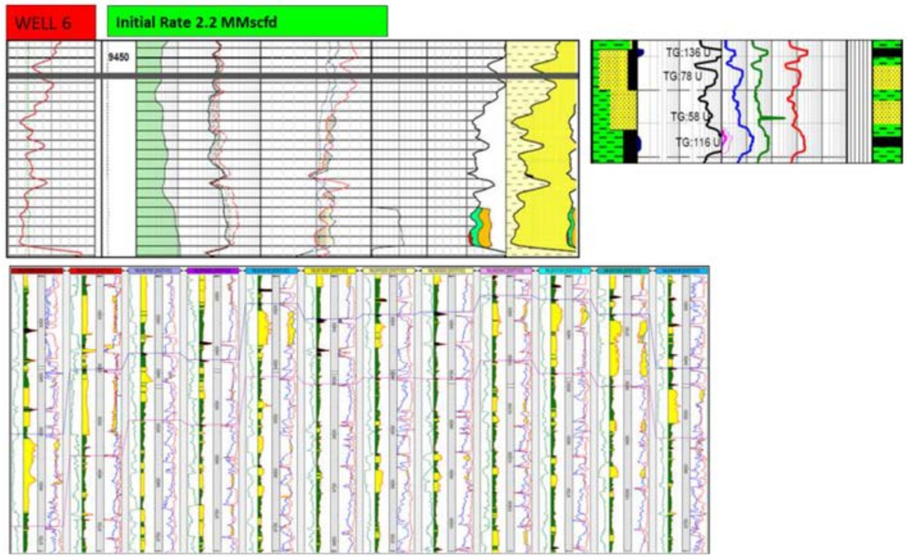

Figure 12—D-64 Well 6

Going the Extra Miles

With the new prospective on defining potential zones, Nilam perforation portfolio is once again sustained without the addition of new well. On paper, the perforation portfolio could give additional 926 MBOE reserve to Nilam Production. In order to achieve that target reserve, straight forward well intervention could not be executed since the potential zone bears associate risk and sometimes is l ocated in between the already perforated zones or in such manner location. Going the extra miles should be done. Quality control and complex well intervention job campaign are two key components which should be performed in order to achieve the target. Described below are the extra miles performed to unlock the potential zones;

Cased Hole Log. Since the by passed zone or unprognosed zones look less desirable to be perforated by only its open hole log, additional justification should be made to transform it into desirable potential zones. Integrated well by well review explained in the previous part is the preliminary review needed to define the zone as potential candidate. After defined as potential, yet it bears 50:50 chance of success unless other approached performed to minimize uncertainties in the potential zone definition. Cased hole log is the most suited technology as quality control in defining the potential unprognosed or by passed zone. PHSS best practice, only for high risk multi candidate unprognosed perforation or potential candidate accessed by complex well intervention needs to be checked using case hole log to minimized its uncertainties.

One good example of case hole log application is on Well-3 E-59 case. As explained in previous section, E-59 on well-3 was defined wet from its open hole log. Well by well review was performed and E-59 was defined as potential with several other high risk potential zone on the same well. On such occasion, case hole log become economical option to be performed as part of quality control to minimize subsurface uncertainties. Case hole log result on E-59 successfully verified the existence of hydrocarbon in the previously defined wet zone and the perforation result confirm it with 51 MBOE cumulative production.

Complex Well Intervention. By Pertamina Hulu Sanga Sanga definition, simple well intervention job is defined as well intervention which comprehend minimum risk and minimum cost. Accordingly, the scope is limited to mechanical isolation using plug, perforation and unload activities while other than that is categorize as complex job. The need of complex job to access the potential zones is caused by the diverse completion type on the existing well stock as illustrated on figure 13. The recent completion known as monobore slim hole completion uses single or dual 3-1/5" tubing cemented into surface also creates another challenge to access the by-pass zones. Two points below are example of complex well intervention job needed to unlock the potential zones.

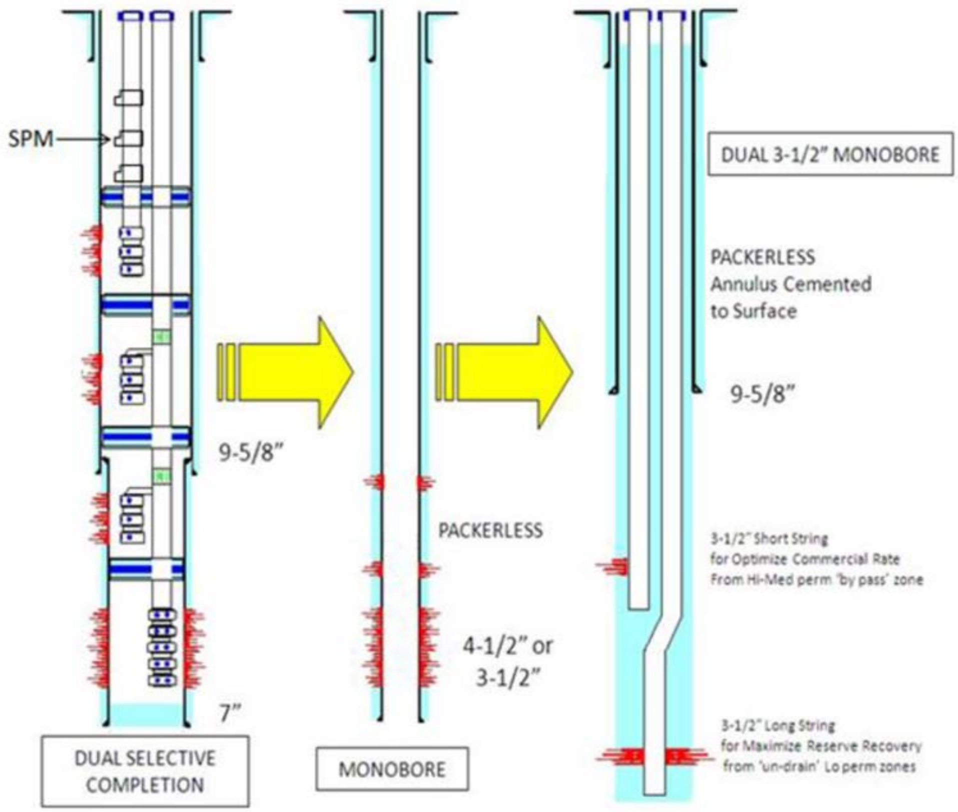

Figure 13—Well completions evolution (after Wijanarko et al. 2012)

1. *Cement Packer*

Several by-pass and unprognosed zones are located on the old well stock (well drilled before 1994) with dual selective completion as illustrated Figure 13. To access potential zones on such completion requires more effort compared to the monobore completion type. The common technique used is by performing recompletion which requires high risk, costly, lengthy, and complex work over operation. But since 1995, PHSS has applied an alternative technique to access by passed zones on dual selective completion by using rigless cement-packer.

Cement packer is a method to place cement in annulus as an additional vertical barrier on the dual selective completion. Figure 14 shows the comparison of dual selective completion pre and post cement packer job. To place cement as additional barrier on such position needs several preparation steps. The first important step is to make sure the existing barrier is well functioned. Accordingly, pressure test needs to be performed on tubing and annulus to check its integrity. Punch hole on the tubing might be performed to create a circulation path between tubing and annulus for cement placement. The punch hole is positioned at the designed bottom of cement on the annulus and circulation test need to be executed to ensure fluid return on the surface line.

After all those pre-job preparations are completed, cement and displacement material is pumped to the annulus as per calculated pumping schedule and placed on the designed cement placement. To control the cement placement, surface return is choked until the pumping schedule completed. Subsequently, pressure test is performed to check the new cement barrier quality including the temperature log survey to ensure the top of cement location. When the new cement barrier is completed and well functioned, perforation of the by-pass zone can be executed as in the cemented monobore completion. When there is anomaly in one of the preparation job, cement packer could be executed with several modification technique depend on the problem faced. A complete and detail cement packer procedure may be found in Idris, M. et al. 2007.

Although cement packer is not a new technique in PHSS, this approach is unpopular since there was easier access to produce the potential zones on the new well stock. But since 2015, new well development activities decreased and this condition gave additional push to re-explore the cement packer option. By going beyond border in defining pay zone, Nilam development team began to do rigless cement packer campaign to access the by-pass zone in dual selective completion. After intensive well review, eight cement packer programs were proposed to access 26 potential by pass zones. Unfortunately, due to several complex issues on the job preparation, only six cement packer programs covering 16 potential by pass zones were executed.

Well 20 cement packer program is one of success story accessing by pass zone using cement packer. Several potential zones were found not perforated yet on an old well with dual selective completion. By applying cement packer method, those potential zones could be accessed and produced. As illustrated on figure 15, well 20 production was cyclic and low flow pre cement packer program. After cement packer job, several potential zones were produced and Well 20 productivity increased in both gas and oil production. Gas lift installation was developed afterwards, to optimize the oil production.

2. *Cement Squeeze*

Other by-pass and unprognosed zones are located on single or dual monobore completion and to access it on such completion possess another challenges. Since the zone is by passed, it is sometimes located below the existing zones. To access it, needs mechanical isolation using tubing patch and perforation pass through tubing patch. Sometimes, mechanical isolation option using tubing patch is unavailable because of unavailable material or obstruction on the wellbore. When mechanical isolation could not be done using tubing patch, more complex cement squeeze isolation is needed prior perforating the by pass zone. Since 2015, there are 48 of complex job executed in cemented monobore completion to access by pass zones. Well B is one of success story accessing by passed zone using cement squeeze. Firstly, injectivity test should be performed to determine treatment parameters and operating limits. Afterward, designed volume of surfactant spacer, cement, and displacement water were pumped using coil tubing and squeezed to design maximum pressure into formation. After cement squeeze, D-50C and D-51C zones were perforated and successfully deliver initial rate 1.9 MMscfd and 2.8 MMscfd with 2500 BOE cumulative production.

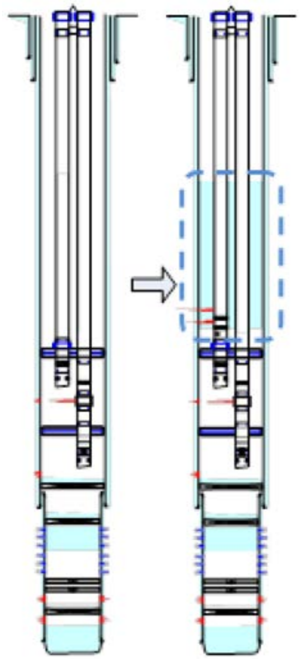

Figure 14—Pre and Post cement packer program

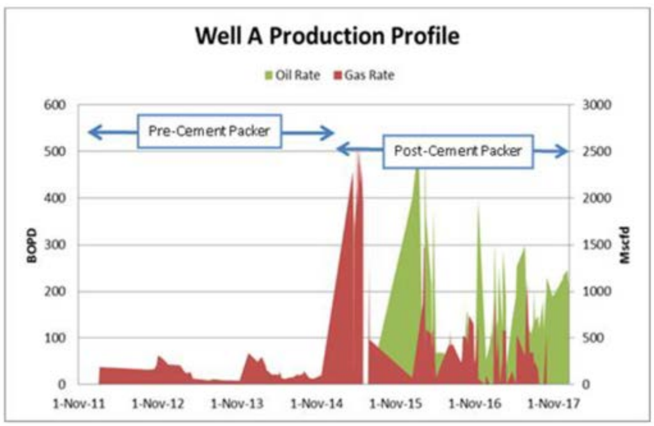

Figure 15—Well 20 Production Profile Pre and Post Cement Packer

Summary

Since 2015 to 2019, there are 486 zones already perforated in Nilam including 129 by pass zones and 8 unprognosed zones. Incremental gains from by pass and unprognosed zones are 4.42 bcf gas, 164,574 bbls liquid (oil and condensate). Success ratio of by pass zones and unprognosed zones are 74%. In summary, unlocking hidden potential have successfully unlocking hydrocarbon potential and maximizing recoverable reserve in existing wells which resulted in extend the field life.

Nomenclature

BOE : Barrel Oil Equivalent
BOPD : Barrels of Oil per Day
PHSS : Pertamina Hulu Sanga-Sanga
LFA : Life Fluid Analyzer
RST : Reservoir Saturation Tool
CO log : Carbon Oxygen log

Bcf : Billion cubic feet
Bbls : Barrels
MMBbls : Million Barrels of Oil

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